Department of the Interior
US Geological Survey

USGS QUALITY ASSURANCE PLAN FOR DIGITAL AERIAL IMAGERY

DIGITAL AERIAL SENSOR TYPE CERTIFICATION

Certification Report for the Microsoft Vexcel UltraCam-Lp

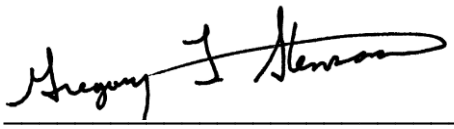
May 2011

DIGITAL AERIAL SENSOR CERTIFICATION REPORT FOR THE
Microsoft Vexcel UltraCam-Lp

Reviewed By:

George Y.G. Lee
Michael Benson
Jon Christopherson
Donald Moe

Reviewed and Approved By:



June 8th 2011

Gregory Stensaas Date
Remote Sensing Technologies Project Manager
US Geological Survey,
Earth Resources Observation Science Center
Sioux Falls, SD 57198

June 8th 2011

Dr. Michael Gruber Date
Chief Scientist Photogrammetry
Microsoft Vexcel

TABLE OF CONTENTS

1 Executive Summary

This report is an adjunct to the previously issued Certification Report for the Microsoft UltraCam-D, X, Xp, and Xp-WA systems. As Vexcel had been previously visited for certification, this report will only cover the UltraCam-Lp system and not duplicate observations reported previously. It is recommended that the prior certification document be reviewed to get a fuller understanding of this certification.

One member of the USGS Aerial Sensor Certification Team, Mr. Donald Moe, visited Microsoft Vexcel (hereafter referred to as *Vexcel*), in Graz, Austria on February 26th and 27th 2010. The purpose of the visit was to discuss the design of the UltraCam-Lp and verify that the manufacturing procedures and processes met or exceeded those for the previously certified UltraCam-D and -X series camera systems. This visit and certification process was conducted under a Technical Assistance Agreement, TAA#: T-06-344, dated 12 Jan 2006, between Microsoft Vexcel and the USGS.

The Vexcel UltraCam-Lp is a four lens aerial mapping system. The system produces a panchromatic image, an RGB image, and an NIR image covering the same ground area. The multispectral imagery (RGB and NIR images) is pan-sharpened by a factor of 2.1 to produce an image that has the same resolution as the panchromatic image.

The UltraCam-Lp system was designed and built by Vexcel. As with the UltraCam-D/-X systems, the key components for this system are produced and assembled by certified suppliers under contract to Vexcel. Final assembly and integration of each UltraCam-Lp system is accomplished at Vexcel in Graz, Austria where the systems are calibrated and tested before delivery to the customer.

The USGS Manufacturer Sensor Certification Team (hereafter referred to as the *Team)* has found the Vexcel UltraCam-Lp System to be designed, manufactured, tested, and supported to the level required to reliably meet the performance claims of the manufacturer when operated within manufacturer's intended operational parameters. These systems, when operated properly by a conscientious and technically qualified operator, are capable of meeting the accuracy claims given by Vexcel for digital aerial data.

2 Purpose and Report Organization

This report summarizes the information provided by Vexcel to the USGS and also information gathered through observations made by the USGS team during the visit to the Vexcel facility in Graz, Austria. Proprietary information has not been included in this report. ***Inquiries for technical information beyond what is in this report should be made directly to Vexcel via the following information****:*

Dr. Michael Gruber
Microsoft Vexcel Imaging GmbH
Anzengrubergasse 8/4
8010 Graz, Austria
michgrub@microsoft.com
+43 316 84 90 66 918

The remainder of this document consists of the following sections.

Section 3: Facility Visit - provides an overview of the trip to Vexcel.

Section 4: System Design, Intended Use, and Expected Accuracy - provides the system description and design overview, intended photogrammetric use, and the expected accuracy of the system.

Section 5: Documentation - provides a synopsis of the documentation acquired by the USGS for the certification process.

Section 6: USGS Findings - documents the findings of the USGS Certification team.

Appendix A: Technical Specifications - provides the generic technical specifications for the UltraCam-Lp system.

3 Facility Visit

The single team member arrived at the Anzengrubergasse facility of Vexcel in Graz, Austria on February 26th, 2010, to begin two days of discussions and facility tours with the staff from Vexcel. The on-site manufacturing facilities were toured in order to inspect where the critical elements of the Vexcel UltraCam-Lp system are built, assembled, and tested. Also inspected was the on-site laboratory where the systems are calibrated.

The Team for the certification process consisted of the following with only Donald Moe making the facility visit:

Gregory Stensaas, USGS EROS/RST Project Chief
Michael Benson, USGS EROS/RST Deputy Project Chief
Jon Christopherson, SGT, contractor to the USGS EROS
Dr. George Lee, USGS, Menlo Park, California
Donald Moe, SGT, contractor to the USGS EROS

Vexcel staff members who presented material and answered USGS questions included:

Markus Bacher
Andreas Drumbl
Dr. Michael Gruber
Dr. Richard Ladstädter
Martin Ponticelli
Alexander Wiechert

4 System Design, Intended Use and Expected Accuracy

4.1 System Description

This section provides a summary of the Vexcel design and system calibration for the UltraCam-Lp system, a description of the intended use of the system, and the accuracy that can be expected from the system. The UltraCam-Lp camera is the "medium" format digital aerial mapping camera product of Vexcel (See Figure 1) that produces the same image accuracy and dynamic range as the large format systems and has all its system components housed within the camera system housing.

Figure 1: The UltraCam-Lp Camera System.

4.2 Basic Design

The basic design concept behind UltraCam-Lp camera is a sensor head (See Figure 2) consisting of four independent camera cones, two of them contributing to the panchromatic image (two leftmost lenses) and two contributing to the multi-spectral image (RGB on upper right and NIR on lower right). The sensor head has four CCD sensor arrays (one for each cone), manufactured by DALSA Corporation. All of these sensors provide a radiometric bandwidth of more than 12 bits.

Figure 2: The UltraCam-L Sensor Unit.

The LINOS/Rodenstock lenses for the UltraCam-Lp are able to resolve 80 lp/mm for the 6 µm pixel grid of the UltraCam-Lp. These systems have lenses with a focal length of 70 mm for the panchromatic cones and 33 mm for the multi-spectral cones. These two sets of lenses support a pan sharpening ratio of 1:2.1 for the UltraCam-Lp.

The panchromatic sensor head has two individual camera heads (i.e., camera cones). These cones have a specific mechanical distance from the camera center which needs to be compensated for during exposure in order to produce a consistent virtual image (See Figure 3). This process is unique for all the UltraCam digital aerial cameras and is known as “syntopic exposure”. It exploits the movement of the aircraft in such way that the shutters of the cones are delayed so they don’t open at the same time (synchronic) but at the same position (syntopic).

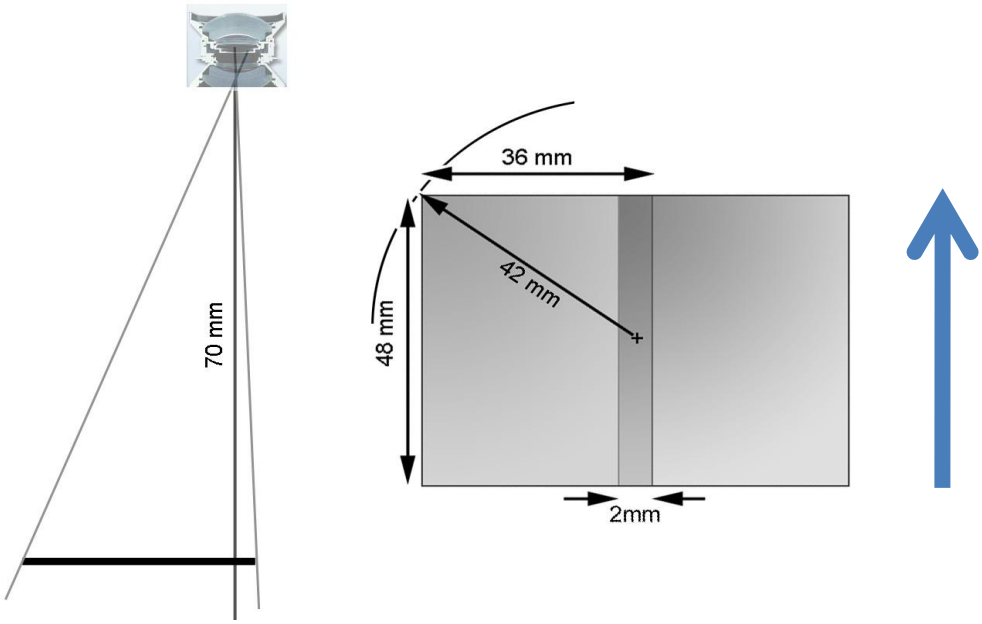


Figure 3: Geometry of the Panchromatic Image.

The UltraCam-Lp camera heads are equipped with CCD sensor products designed and manufactured by DALSA (now TELEDYNE DALSA). The panchromatic part (two separate camera cones) carry each one FTF6080M monochrome sensor at a pixel size of 6 µm by 6 µm and an image format of circa 6000 pixel by 8000 pixel (36 mm by 48 mm). The color cone is equipped with the FTF6040C Bayer Pattern color CCD at 6 µm by 6 µm pixel size (6000 by 4000 pixel) and the near infrared sensor head carries the FTF6040M monochrome CCD sensor of the same size.

4.3 Radiometric Properties

The radiometric bandwidth of the UltraCam is based on the dynamic range of the CCD sensor arrays (> 12 bit or >72 dB). The analog signal is converted into a digital signal by the 14 bit ADC and all of the image data are stored at a bandwidth of 16 bit.

The band separation is based on Bayer Pattern micro-filters attached to the Color CCD. The RGB and pan lenses are also equipped with Infrared cut off filters and the infrared channel is equipped with a 690nm IR filter. The spectral signatures of the panchromatic, infrared and RGB are graphically shown in Figures 4a and 4b.

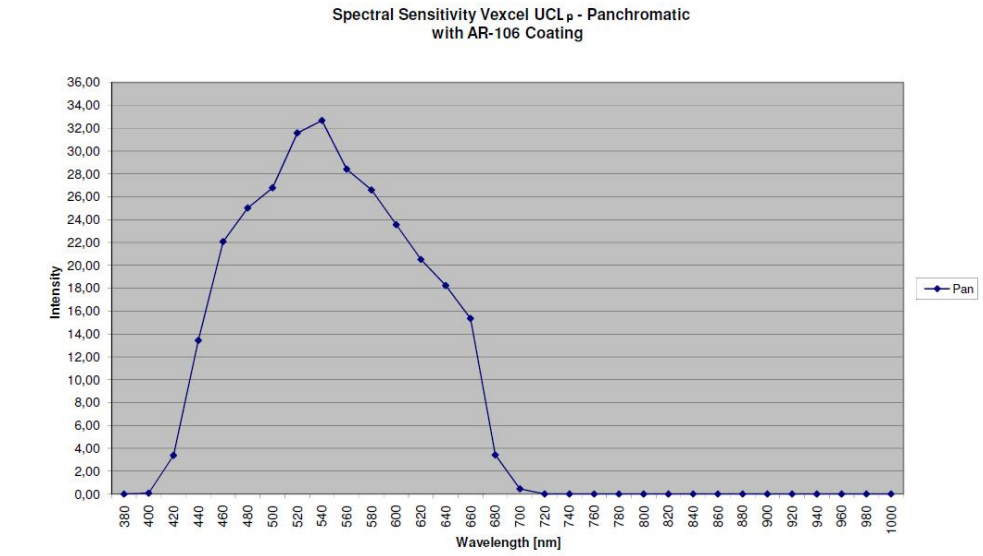


Figure 4a: UltraCam-Lp Panchromatic Spectral Sensitivity

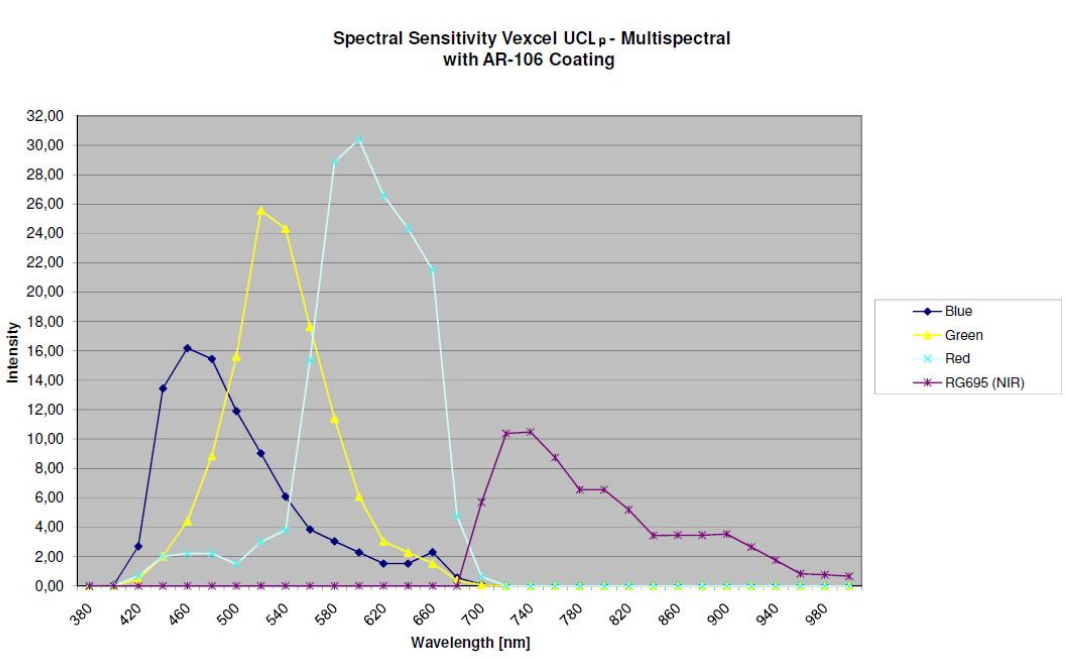


Figure 4b: UltraCam-Lp 4-band Spectral Sensitivity

UltraCam-Lp image data are collected at a 12+ bit level (analog signal), converted to digital at a 14 bit level (14 bit ADC), and stored without compression at a 16 bit level (the so-called raw data). Images are not compressed beginning with the Level-0 (raw) through the Level-2 (initial image, 16-bit, temporary TIF) processes. At Level-3 (final image), user-selected manipulations such as pan sharpening or number of bits/pixel are applied and there is an option for the user

to select JPEG compression or uncompressed TIF. Conversion to 8-bit from 16-bit data is accomplished using gradation curves.

The radiometric calibration of the UltraCam sensor head is done by taking a set of more than 300 images and then automatically processing these images in order to detect defective pixels, lens vignetting, and pixel based offset and gain values for each CCD sensor element. During the radiometric calibration the shutter response time is also measured and stored for each individual shutter.

The result of the laboratory calibration is documented in the delivered camera calibration report. The calibration parameters relevant to the post processing of the imagery are stored in the camera calibration dataset.

4.4 Geometric Calibration

The routine calibration of the UltraCam-Lp sensor head takes place in the calibration laboratory at the Anzengrubergasse facility. The calibration laboratory consists of a three dimensional calibration target with 367 circular marks (See Figure 5). These marks are surveyed to an accuracy of about +/- 0.1 mm in X, Y and +/- 0.2 mm in Z and show a well defined circular pattern. The dimensional size of the entire structure is 8.4m by 2.5m at the rear wall and 2.4m in depth. Rear wall, ceiling and floor carry 70 metal bars with 280 marks; four additional vertical bars in the center of the structure carry 16 marks; 98 marks are mounted at the rear wall. The mean distance between marks is about 30cm.

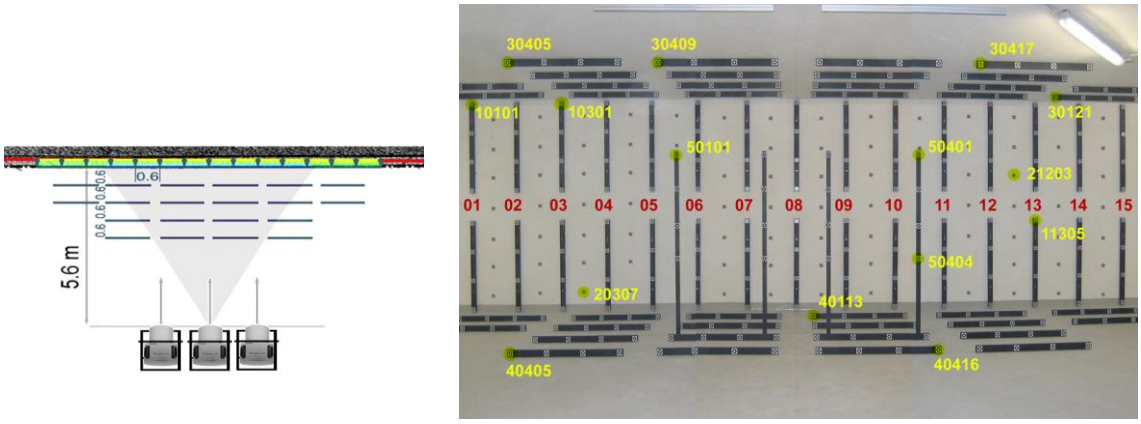


Figure 5: Camera Calibration Laboratory

Layout of the Lab (top) and Photo of the 3D Targets (bottom)

The data capture of 84 images is taken from three different camera stations in such way that the camera is tilted and rotated. Software is used to compute sub-pixel accurate image positions of each mark in each image of the entire set of images. This results in a dense and complete coverage of coordinate measurements over the entire the image format. A single calibration dataset consists of almost 90,000 measured image points.

The unknown camera parameters are computed and a distortion lookup table is generated. During the data capture process, the temperature in the laboratory is recorded such that a delta focal length correction can be applied based on the temperature at the time of exposure. After the distortions are determined for each lens cone, the relative locations of the two panchromatic cameras are derived using epipolar transforms which are stored with the other calibration data. The two pan images go through a monolithic stitching process using tie points in the pan overlap region and tie points between each pan image and the green band image (the geometric reference), which covers the extent on both pan images.

4.5 Intended Use

According to Vexcel, the UltraCam-Lp digital aerial camera has been designed for any type of aerial monoscopic or stereoscopic photogrammetric application. It can support high and low altitude missions while collecting four-band multispectral (red, green, blue, and near infrared) and panchromatic imagery simultaneously.

For large scale mapping, the fast cycle rates and the special exposure concept of syntopic exposure control allows the system to collect down to a ground pixel size of < 5 cm (< 2 inches). The inclusion of large capacity solid state drives (SSDs) for on-board storage also directly supports large scale activities. For medium and small scale mapping, flight altitudes up to 4500 meters (15,000 feet) in non-pressurized aircraft are supported.

4.6 Expected Accuracy

The expected accuracy values presented in the following tables were provided by Vexcel. These accuracies were derived on the basis of a small orthophoto project area consisting of a single mosaicked orthophoto from four images, two from each of two strips of imagery covering the area of interest.

According to the manufacturer, the UltraCam-Lp has the expected accuracies as shown in Table 1.

Table 1: Expected Accuracy of UltraCam-L

Resolution (GSD)	CE95 Accuracy					
	With GPS/IMU			Without GPS/IMU		
	Number of Control Points			Number of Control Points		
	0	1	4	0	1	4
1 Meter	N/A	N/A	N/A	N/A	N/A	N/A
12-inch (30cm)	10”	10”	9”	N/A	N/A	10”
6-inch (15cm)	5.0”	5.0”	5.0”	N/A	N/A	5”
3-inch (7.5cm)	4”	4”	3”	N/A	N/A	3”
Highest advertised resolution: 1.2–inch (3 cm)	N/A	N/A	N/A	N/A	N/A	N/A

5 Documentation

Prior to the facility visit, the Team reviewed various documents received from Vexcel and public domain documents retrieved primarily from the internet. Detailed comments and questions were derived from these materials and were deemed to be at a level that did not to require formal answers prior to the facility visit but could be answered during the visit.

During the visit, the Vexcel staff presented and/or provided additional documents that included the following:

1. Design Documentation
2. Geometric Calibration
3. Sample Calibration Report
4. Copies of Published Technical Papers
5. Technical Specification Sheets
6. Technical Paper on Monolithic Stitching

There were no additional documents required after the facility visit for the UltraCam-Lp.

Finally, the visiting member of the Team took notes, pictures, and wrote comments regarding what he saw and heard during the visit to Vexcel and while researching the UltraCam-L system. Copies of notes have been collected and are filed with the Vexcel Certification files at the USGS EROS.

Copies of all documentation described above are kept in the UltraCam Certification files for the entire family of sensors at the USGS EROS for future reference by the Team. Many of these documents and the information within or derived from are Vexcel proprietary information.

6 USGS Team Findings

Prior to the visit with Vexcel, the Team was provided technical information, datasheets and relevant documentation. During the visit, updated materials were provided along with detailed presentations and the single team member took notes. The Team also researched other sources of information from various sources to augment the understanding of the Vexcel UltraCam-Lp. The Team notes and various materials containing proprietary information are not included in this report but are kept on file with the USGS for future internal reference.

The quality program, system engineering processes, quality processes, geometric and radiometric calibration, software engineering, service policy, and verification of technical performance met or exceeded those from the UltraCam-X family of sensors as documented in their sensor certification document.

The Team has found the Vexcel UltraCam-Lp System to be designed, manufactured, tested, and supported to the level required to reliably meet the performance claims of the manufacturer when operated within manufacturer's intended operational parameters. These systems, when operated properly by a conscientious and technically qualified operator, are capable of meeting the accuracy claims given by Vexcel for digital aerial data.

Appendix A: UltraCam-Lp Technical Specs

General Information:

Component	Capability	Specification	Comment
System			
	System Nomenclature	UltraCam-Lp	
	Number of Lens Cones	4	
	Number of Sensor Chips/Lines	4	
	On-board Storage (GB/TB)	1.0 TB per Data Unit	Unlimited with use of multiple storage units.
	On-board Storage (images)	2500 per Data Unit	Unlimited with use of multiple storage units.
	Image Storage Redundancy (Y/N)	Y	
	Power Consumption (Watts)	220 W	At full performance.
	Camera Temperature Range (°C)	0°C to +45°C	Storage temperature from -20°C to 65°C.
	Computer Temperature Range (°C)	0°C to +45°C	
	Humidity Range	95% @ no condensation	
	Mount Type	GSM3000, T-AS, PAV30, PAV80	
	Output Pixel Size(s)	11,704 x 7,920	
	Fwd Motion Comp (FMC) Type	TDI controlled	
	Maximum FMC Correction (pixels)	50 pixel	
	Recommended Forward Overlap (%)	Project requirements.	80% FOL @ 10 cm GSD @ SOG 63 m/sec 60% FOL @ 5 cm GSD @ SOG 63 m/sec
	Recommended Side Overlap (%)	Project requirements.	
Size/Weight	(W x D x H in cm & Wt in kg)		
	Camera Size/Weight	45 x 45 x 80 cm / 55kg	
	Processing System Size/Weight	50 x 36 x 65 cm / 65kg	
	Storage System Size/Weight	40 x 30 x 20 cm / 16 kg	
	Mount Weight	Model dependent.	
	Total System Weight	136kg	
Controls			
	Exposure Control Options	Time & Aperture	
	Light Metering Type	Manual settings	
	Shutter Type	Prontor magnetic 0 - Vexcel	
	Shutter Speed Range	1/500 to 1/32	
	ISO Range	N/A	
	Exposure Compensation	N/A	

Component	Capability	Specification	Comment
Geom/Geod Accuracy			
	Image RMS Acc. (microns)	+/- 2µm	
	Effective GSD Factor at Nadir (Spatial Ground Resolution / GSD)	1	
	Eff. GSD Factor at Max FOL (Spatial Ground Resolution / GSD)	10cm GSD @ 80% FOL	
	Differential GPS	N/A	Optional, 3rd party products.
	- Position (m)	N/A	
	- Velocity (m/sec)	N/A	
	- Roll / Pitch (deg)	N/A	
	- True Heading (deg)	N/A	
	Post Processed GPS	N/A	Optional, 3rd party products.
	- Position (m)	N/A	
	- Velocity (m/sec)	N/A	
	- Roll / Pitch (deg)	N/A	
	- True Heading (deg)	N/A	

Panchromatic Camera(s):

Component	Capability	Specification	Comment
Sensor			
	Sensor Type	CCD	
	Sensor Nomenclature	Dalsa FTF6080-M	
	Total Pixels (MP)	92 MP	
	Along Track Pixels	11,704	
	Cross Track Pixels	7,920	
	Aspect Ratio	1:1	
	Pixel Size (mm)	0.006	
	Fill Factor (%)	90%	
	Radiometric Resolution (bits)	12+ bit	
	Dynamic Range	>72 db	
	Max Exposure Rate (sec)	1/500	
Lens			
	Lens Type	Linos Rodenstock	
	Lens Nomenclature	Linos Vexcel Apo-Sironar Digital HR	
	Focal Length (mm)	70 mm	
	Aperture Range (f-stop)	1/5.6	
	Along Track FOV (deg)	37°	
	Cross Track FOV (deg)	52°	
Spectral Response			
	Panchromatic	410 - 690 nm	
	Blue	N/A	

Component	Capability	Specification	Comment
	Green	N/A	
	Red	N/A	
	NIR	N/A	
Virtual Image	(if applicable)		
	Total Pixels (MP)	92	
	Along Track Pixels	11,704	
	Cross Track Pixels	7,920	
	Aspect Ratio	1 : 1.48	
	Pixel Size (mm)	0.006	
	Along Track FOV (deg)	37°	
	Cross Track FOV (deg)	52°	
	Radiometric Resolution (bits)	12+ bit	
	Dynamic Range	>72 db	

NIR Channel:

Component	Capability	Specification	Comment
Sensor			
	Sensor Type	CCD	
	Sensor Nomenclature	Dalsa FTF6040-M	
	Total Pixels (MP)	19.2 MP	
	Along Track Pixels	5,320	
	Cross Track Pixels	3,600	
	Aspect Ratio	1:1	
	Pixel Size (mm)	0.006	
	Fill Factor (%)	90%	
	Radiometric Resolution (bits)	12+ bit	
	Dynamic Range	72+ db	
	Max Exposure Rate (sec)	1/500	
Lens			
	Lens Type	Linos Rodenstock	
	Lens Nomenclature	Linos Vexcel Apo-Sironar Digital HR	
	Focal Length (mm)	33 mm	
	Aperture Range (f-stop)	1/4.0	
	Along Track FOV (deg)	37°	
	Cross Track FOV (deg)	52°	
Spectral Response			
	Panchromatic	N/A	
	Blue	N/A	
	Green	N/A	
	Red	N/A	
	NIR	690 - 1000 nm	
Virtual Image	(if applicable)		
	Total Pixels (MP)	19.2	

Component	Capability	Specification	Comment
	Along Track Pixels	5,320	
	Cross Track Pixels	3,600	
	Aspect Ratio	1 : 1.48	
	Pixel Size (mm)	0.006	
	Along Track FOV (deg)	37°	
	Cross Track FOV (deg)	52°	
	Radiometric Resolution (bits)	12+ bit	
	Dynamic Range	>72 db	

RGB-CIR Camera(s):

Component	Capability	Specification	Comment
Sensor			
	Sensor Type	CCD	
	Sensor Nomenclature	Dalsa FTF6040-C	
	Total Pixels (MP)	19.2 MP	
	Along Track Pixels	5,320	
	Cross Track Pixels	3,600	
	Aspect Ratio	1:1	
	Pixel Size (mm)	0.006	
	Fill Factor (%)	90%	
	Radiometric Resolution (bits)	12+ bit	
	Dynamic Range	72+ db	
	Max Exposure Rate (sec)	1/500	
Lens			
	Lens Type	Linos Rodenstock	
	Lens Nomenclature	Linos Vexcel Apo-Sironar Digital HR	
	Focal Length (mm)	33 mm	
	Aperture Range (f-stop)	1/4.0	
	Along Track FOV (deg)	37°	
	Cross Track FOV (deg)	52°	
Spectral Response			
	RGB (if applicable)		
	- Blue	400 - 580 nm	
	- Green	480 - 630 nm	
	- Red	560 - 680 nm	
	CIR (if applicable)		
	- Green	480- 630 nm	
	- Red	560 - 680 nm	
	- NIR	690 - 1000 nm	
Virtual Image	(if applicable)		
	Total Pixels (MP)	19.2	
	Along Track Pixels	5,320	
	Cross Track Pixels	3,600	
	Aspect Ratio	1 : 1.48	

Component	Capability	Specification	Comment
	Pixel Size (mm)	0.006	
	Along Track FOV (deg)	37°	
	Cross Track FOV (deg)	52°	
	Radiometric Resolution (bits)	12+ bit	
	Dynamic Range	>72 db	